Antiferromagnetic Multilayers and Superlattices (FWP 58918)

Scientific Achievement

We have created magnetic multilayers and superlattices as model experimental systems to address some classical and current issues in antiferromagnetism. With antiferromagnetically-coupled Fe/Cr superlattices, we confirmed the long-ago predicted surface spin flop transition in finite antiferomagnets. We traced the evolution of the magnetic structure with changing applied magnetic field using polarized neutron reflectivity at IPNS. Using dynamic micromagnetic simulations and mean-field nonlinear mapping calculations, we examined the stability of the surface spin flop transition in a finite uniaxial antiferromagnetic Fe/Cr superlattice when the applied magnetic field is canted with respect to the easy axis, and determined the phase diagram. The calculated critical angle below which the surface spin-flop transition exists is in quantitative agreement with experimental measurements. However, comparison between experiments and simulation also indicates that the broadening of the transition is possibly the result of sample inhomogeneity and interface roughness.

With antiferromagnetically-coupled Fe/Gd multilayers as an artificial ferrimagnet, we characterized the low-field surface nucleation and evolution of the inhomogeneous magnetic state via grazing-incidence x-ray magnetic circular dichroism at APS. We delineated the phase diagram and observed that surface termination has a dramatic effect on the nature of the inhomogeneous state. We show that the magnetic profile within the Gd layers is inhomogeneous. The enhanced Gd magnetization near the interface arises from its proximity to magnetically ordered Fe.

Significance

Magnetic systems with antiferromagnetic interactions exhibit phenomena that range from the intellectually challenging, such as spin-density-wave antiferromagntism, to the practically important, such as exchange-bias in information storage. However, our understanding of antiferromagnetism has traditionally not been as comprehensive as that of ferromagnetism, due to the lack of suitable experimental system and characterization tools. Utilizing magnetic multilayers and superlattices as a versatile platform to create model experimental systems amenable to available tools, we capture the essential physics and address the effects of interface on the behaviors of magnetic heterostructures.

In the future, we plan to utilize the geometrical confinement and interfacial spin frustration to tune the spin-density-wave antiferromagntism in Cr-based multilayers and to explore the nature of quantum critical phenomena in a classical antiferromagnet whose electronic and magnetic behaviors are intimately related.

Performers

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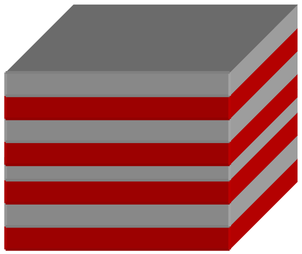
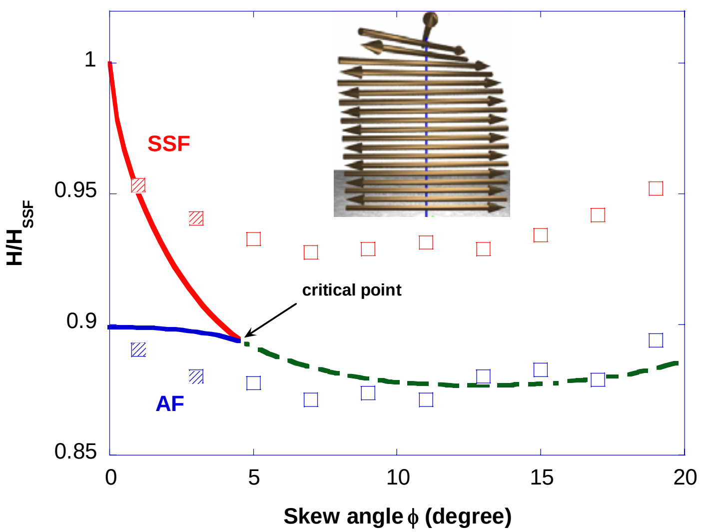
Antiferromagnetic Multilayers and Superlattices

The new challenge in nanomagnetism is to obtain an understanding of antiferromagnets (AF) that is as comprehensive as that of ferromagnets

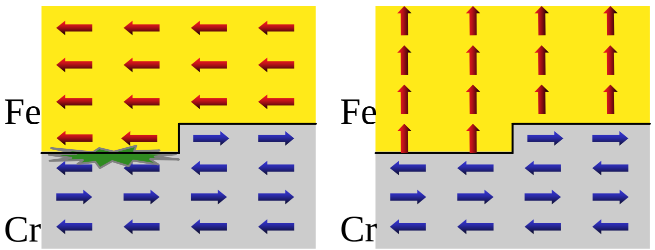


Layered structures

- Geometric confinement
- Proximity effect



Phase diagram of Surface spin flop in finite AF



Access quantum critical point by tuning interfacial spin frustration

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